The Journal of Thoracic and Cardiovascular Surgery
February 1996

are excellent conduits and should be used if there is any question regarding adequate length.

My second comment is in regard to the use of the electrocautery in the skeletonization technique of ITA dissection. In their article comparing the effects of monopolar and bipolar cauterization on skeletonized ITA's, Yoshida and associates[3] go into detail describing the damaging effects of the two cauterization techniques on these relatively fragile arteries. I suggest that the arteries would sustain far less damage and hemostasis would be immediate and secure if hemoclips, rather than cautery, are used on the ITA branches. As described in our article,[2] thermal trauma to the ITA is thus specifically avoided. If meticulous clip application techniques are used and scrupulous attention is paid to the details of the dissection, fewer than 1% of skeletonized ITAs are unsuitable conduits.

One of the main advantages to the use of arterial conduits is their longevity. I therefore propose that conduit life will remain optimum if we do our best to use harvesting techniques that keep arterial wall and intimal trauma to an absolute minimum.

James M. Cunningham, MD, FACS
Columbus, GA 31904

REFERENCES

1. Kushwaha SS, Bustami M, Tadjkarimi S, Ilsey CD, Mitchell AG, Yacoub MH. Late endothelial function of free and pedicled internal mammary artery grafts. J THORAC CARDIOVASC SURG 1995;110:453-62.
2. Cunningham JM, Gharavi MA, Fardin R, Meek RA. Considerations in the skeletonization technique of internal thoracic artery dissection. Ann Thorac Surg 1992;54:947-51.
3. Acedia H, Wu MH, Kouchi Y, Onuki Y, Shi Q, Sauvage LR. Comparison of the effect of monopolar and bipolar cauterization on skeletonized, dissected internal thoracic arteries. J THORAC CARDIOVASC SURG 1995;110:504-10.

12/8/69755

Reply to the Editor:

We appreciate Dr. J. M. Cunningham's comments and agree that skeletonization is a technique relatively frequently used by us and others to enable the pedicled internal thoracic artery to reach more peripheral sites. Although this technique increases the chances of using a pedicled graft, to our knowledge its effect on endothelial function has not been studied. We agree with Dr. Cunningham that avoiding the use of diathermy near the vessel can (at least in theory) prevent or minimize endothelial damage. The effect of stripping the adventitia and stretching the artery, or the vessel wall in general and the endothelium in particular, remains unknown. Provision of data regarding this could be a welcome addition to the literature.

The almost unique structural and functional characteristics of the internal thoracic artery, coupled with its documented superior performance as a bypass graft, warrant efforts aimed at maximizing its use.

Magdi Yacoub, FRCS
Sudhir S. Kushwaha, MD
National Heart and Lung Institute
Harefield, Middlesex
UB9 6JH, United Kingdom

12/8/69754

What is cerebral metabolism during retrograde perfusion?

To the Editor:

We appreciate the experimental research on the pharmacologic improvement of retrograde cerebral perfusion by Yoshimura and associates.[1] Brain edema, a topic of investigation because of the broad use of this type of perfusion, was noted in the article to be alleviated by addition of mannitol and an antivasospastic agent, with the reduction of cerebral vascular resistance. The data shown encourage clinical trials of pharmacologic support to reduce the morbidity after aortic arch procedures.

The perfusion method of Yoshimura and associates,[1] however, is extremely different from clinical or other experimental retrograde brain (cerebral) perfusion methods. Yoshimura and associates[1] perfused the dogs through the bilateral maxillary veins while draining blood from the right atrium instead of the aorta. It is not clear why they performed this curious veno-venous bypass perfusion as "retrograde cerebral perfusion."

Fig. 1 demonstrates how small the brain is compared with the total area perfused through bilateral maxillary veins. This well-developed venous network would steal the perfused blood from the brain. This shunt flow can be reduced when the pressures in the azygos vein and the superior vena cava are maintained high, as in our previous study.[2] Contrarily, drainage from the right atrium should magnify this shunt flow from the brain through the superior vena cava, azygos vein, and other veins. Then the intracranial sinuses should collapse, even if the maxillary vein pressure is maintained as shown in Yoshimura and associates' article.[1] Their veno-venous bypass perfusion therefore never establishes effective retrograde circulation in the brain. The low and decreasing intracranial pressures shown in the article are evidence of a perfusion failure because the intracranial pressure is known to increase as the perfusion pressure increases during retrograde brain perfusion.[3] Apparently, the brain edema shown in the article is caused by absence of circulation in the brain tissue but not by excess blood flow into the intracranial sinuses.

Furthermore, their data on the cerebral metabolism disagree with the knowledge obtained to date.[4-6] At 20° C, cerebral metabolic rate for oxygen ($CMRO_2$) is a constant value (0.35 to 0.55 ml · 100 gm^{-1} · min^{-1}) that does not

The Journal of Thoracic and
Cardiovascular Surgery
Volume 111, Number 2

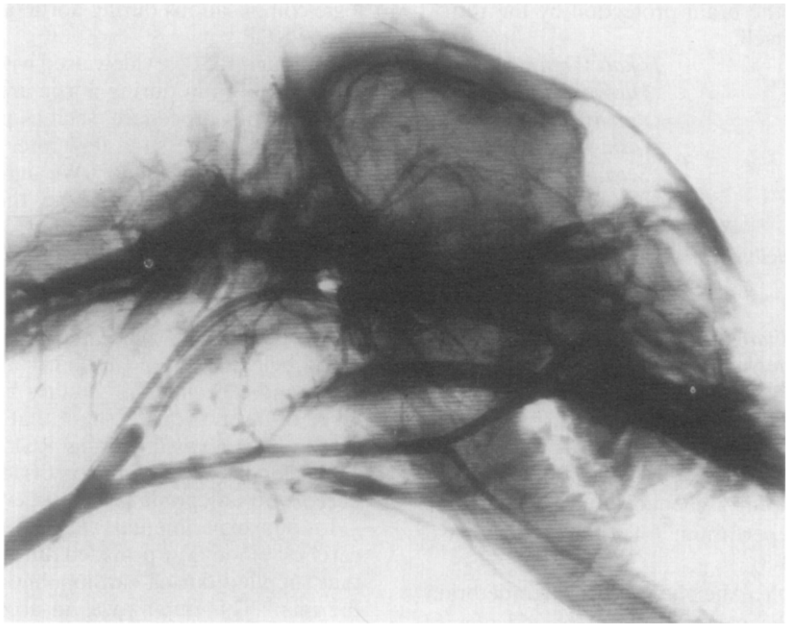

Fig. 1. An angiogram through bilateral internal maxillary veins demonstrates intracranial sinuses and extracranial veins as a dense network. The head and neck veins permit the blood to escape from the brain to the body.

increase even with "luxury" perfusion. A greater value than this was presented in the article as $CMRO_2$ during the maxillary vein perfusion. Oxygen demand in the brain is a temperature-dependent value not affected by cerebral blood flow (CBF). $CMRO_2$ does not exceed this value even if a retrograde perfusion gives the brain "luxury" blood flow. Retrograde brain perfusion should cause a large amount of nonfunctional shunt blood flow on the brain surface as well as in the extracranial circulation. This shunt flow should be included in the CBF value when derived by hydrogen clearance methods.[2, 7] When laser photometry is used, the CBF overestimation can be reduced if the probe position is carefully selected with continuous recording of the value, as we have done.[2] The veno-venous bypass perfusion of Yoshimura and coworkers,[1] however, would have further magnified the shunt flow on the brain surface but extinguished the capillary blood flow in the brain tissue. There, the CBF would be replaced by this magnified shunt blood flow. The CBF value obtained with a fixed probe during the "retrograde cerebral perfusion" of Yoshimura and associates[1] is an extreme example of methodologic overestimation of CBF. Their extraordinary $CMRO_2$ value was calculated with this unacceptable CBF value.

In addition, as Fig. 1 demonstrates, the CBF cannot be isolated when the brain is perfused retrogradely but not antegradely.[8] The brain weight was only $0.67\% \pm 0.09\%$ of the body weight in 31 dogs used in our previous study.[6] Granted that the CBF value shown by Yoshimura and associates[1] was true, the total blood flow in the brain was less than 11 ml/min. It is estimated as 5% of total perfusion flow rate in this experiment. As Fig. 1 and the anatomy of cranial vessels in the dog show, a large amount of the blood should flow into the carotid artery from the skull and from the extracranial part, but surprisingly small amount should flow from the brain. Data in their experiment therefore did not reflect the metabolic rate of the brain at all.

We believe that the brain protection during retrograde brain perfusion should be physiologically examined as follows: (1) Effective retrograde circulation should be established in the brain experimentally beyond the venous valves with blockage of the flow escaping through the well-developed veno-venous shunt pathways. For this purpose, the superior vena cava and the upper part of azygos vein should be simultaneously perfused or at least ligated, and the blood must be drained from the aorta but never from the right atrium nor from the superior vena cava. Pressure should be simultaneously monitored in the superior vena cava, the sagittal sinus, and the aorta to clarify the true driving pressure. Then the true functional blood flow through the brain capillary bed and the $CMRO_2$ should be examined during retrograde brain perfusion by some precise measurements. Sophisticated knowledge of this fundamental physiology will clarify the optimal condition for retrograde brain perfusion to protect the brain and reduce or eliminate brain edema. Thereafter, pharmacologic interventions should be tested, with correct

The Journal of Thoracic and
Cardiovascular Surgery
February 1996

baseline estimation of the brain protection by the retrograde brain perfusion itself.

Takao Watanabe, MD[a]
Hiroyuki Saitou, MD[a]
Ji Wei Zhang, MD[b]
Yoshiyuki Iijima, MD[a]
Setsuo Kuraoka, MD[a]
Yasuhisa Shimazaki, MD[a]
Second Department of Surgery
Yamagata University School of Medicine
Iida-Nishi, 990-23
Yamagata, Japan[a]
Shanghai Second Medical University
Shanghai, People's Republic of China[b]

REFERENCES

1. Yoshimura N, Okada M, Ota T, Nohara H. Pharmacologic intervention for ischemic brain edema after retrograde cerebral perfusion. J THORAC CARDIOVASC SURG 1995;109:1173-81.
2. Watanabe T, Iijima Y, Abe K, et al. Retrograde brain perfusion beyond the venous valves. Hemodynamics and intracellular pH mapping. J THORAC CARDIOVASC SURG 1995;109:1173-81.
3. Usui A, Oohala K, Liu T, et al. Determination of optimum retrograde cerebral perfusion condition. J THORAC CARDIOVASC SURG 1994;107;300-8.
4. Fox LS, Blackstone EH, Kirklin JW, Bishop SP, Bergdahl LA, Bradley EL. Relationship of brain blood flow and oxygen consumption to perfusion flow rate during profoundly hypothermic cardiopulmonary bypass. J THORAC CARDIOVASC SURG 1984;87:658-64.
5. Miyamoto K, Kawashima Y, Matsuda H, Okuda A, Maeda S, Hirose H. Optimal perfusion flow rate for the brain during deep hypothermic cardiopulmonary bypass at 20° C. J THORAC CARDIOVASC SURG 1986;92: 1065-70.
6. Watanabe T, Washio M. Pulsatile low-flow perfusion for enhanced cerebral protection. Ann Thorac Surg 1993;56:1478-81.
7. Usui A, Hotta T, Hiroura M, et al. Retrograde cerebral perfusion through a superior vena caval cannula protects the brain. Ann Thorac Surg 1992;53:47-53.
8. Michenfelder JD, Messick JM Jr, Theye RA. Simultaneous cerebral blood flow measured by direct and indirect methods. J Surg Res 1968;8:475-81.

12/8/69671

Reply to the Editor:

We thank Watanabe and associates for their interest in our recent article, "Pharmacologic intervention for ischemic brain edema after retrograde cerebral perfusion."[1] We reported that the supply of oxygen or glucose by retrograde cerebral perfusion (RCP) was not enough to maintain sufficient cerebral metabolism and that this may cause brain edema after antegrade cerebral blood perfusion is resumed. We therefore recommended cerebral protection with pharmacologic agents to prevent neurologic complications during aortic arch operation with the use of RCP.[1]

Although RCP is widely used with satisfactory results to protect the brain during aortic arch operation, the standards for this procedure, such as perfusion site, drainage site, perfusion pressure, flow rate, and temperature, have not yet been established.[2] We agree with Watanabe and associates that drainage from the right atrium should increase the veno-venous shunt, which may reduce the cerebral protective effect of RCP. As we explained in our article, however, the pressure gradient between the maxillary veins and systemic arteries caused retrograde cerebral blood flow, which was evidenced by desaturated blood being returned to the carotid artery. Several clinical[3, 4] and experimental[5] studies have suggested the existence of a veno-venous shunt that does not participate in cerebral metabolism during RCP, and the veno-venous shunt is considered a major disadvantage of RCP compared with antegrade selective cerebral perfusion.

In our experimental studies, we observed that the cerebral blood flow provided during RCP was only half of that supplied during cardiopulmonary bypass with hypothermia.[1] This finding was in accord with the results of other experimental studies.[2, 6] A limitation of our study was the determination of cerebral blood flow, including veno-venous shunt flow, as Watanabe and associates pointed out. It is difficult, however, to distinguish the true functional blood flow that participates in cerebral metabolism from veno-venous shunt flow during RCP in the experimental study. Accurate measurement of the true functional blood flow, if possible, should enable us to precisely evaluate cerebral metabolism during RCP. We therefore hope that Watanabe and associates' experimental study will clarify the true functional blood flow during RCP by means of laser photometry.

Naoki Yoshimura, MD
Masayoshi Okada, MD
Toshiaki Ota, MD
Hideaki Nohara, MD
Department of Surgery, Division II
Kobe University School of Medicine
Kobe, Japan

REFERENCES

1. Yoshimura N, Okada M, Ota T, Nohara H. Pharmacologic intervention for ischemic brain edema after retrograde cerebral perfusion. J THORAC CARDIOVASC SURG 1995;109:1173-81.
2. Nojima T, Magara T, Nakajima Y, et al. Optimal perfusion pressure for experimental retrograde cerebral perfusion. J Card Surg 1994;9:548-59.
3. Yoshimura N, Ataka K, Okada M, Yamashita C, Yoshimura K, Kobayashi S. Ophthalmoscopic findings demonstrate reduced cerebral blood flow during retrograde cerebral perfusion. J THORAC CARDIOVASC SURG 1995;109:591-3.
4. Yasuura K, Okamoto H, Ogawa Y, et al. Resection of aortic aneurysms without aortic clamp technique with the aid of hypothermic total body retrograde perfusion. J THORAC CARDIOVASC SURG 1994;107:1237-43.